Inferential Statistics: An Introduction

Learning how researchers use sample data to make evidence-based conclusions about populations

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ORIENTATION

Lecture Overview

1 **Foundations**

population, sample, parameter, statistic, sampling error

2 **Estimation**

point estimates, confidence intervals, standard error

3 **Testing**

hypotheses, p-values, significance, errors and power

4 **Application**

test selection, assumptions, examples, ethics and practice

Big idea: inferential statistics is about making justified claims while acknowledging uncertainty.

OUTCOMES

Learning Objectives

Objective 1

Distinguish descriptive statistics from inferential statistics.

Objective 2

Define population, sample, parameter, statistic, sampling error and standard error.

Objective 3

Explain how sampling distributions support estimation and hypothesis testing.

Objective 4

Interpret confidence intervals, p-values and statistical significance in simple language.

Objective 5

Identify common inferential tests and the conditions under which they are used.

Objective 6

Recognize limitations, ethical issues and best practices in statistical inference.

Introduction: Why Inferential Statistics Matters

In research, it is usually impossible or unnecessary to study every member of a population. Inferential statistics provides tools for drawing conclusions about a larger group using data collected from a sample.

Academic purpose

Estimate unknown population values, test research hypotheses and quantify uncertainty.

Research purpose

Support evidence-based claims while making clear how much uncertainty remains.

Decision purpose

Guide practical decisions in health, education, business, psychology, IT and policy.

Inferential statistics does not prove a claim with absolute certainty; it evaluates how strongly data support a conclusion.

Key Definitions

Term	Student-friendly meaning	Example
Population	Entire group the researcher wants to understand	All undergraduate students at a university
Sample	Subgroup selected from the population	350 students who completed a survey
Parameter	True population value, usually unknown	Average GPA of all students
Statistic	Value calculated from sample data	Average GPA of the 350 students
Inference	Reasoned conclusion about a population from sample evidence	Estimating the university-wide average GPA

Background and Academic Context

Inferential statistics developed from probability theory, sampling theory and the need to make decisions under uncertainty. Modern research uses inference to evaluate evidence rather than relying on intuition alone.

1 **Probability theory**

Provides the language for random variation and uncertainty.

2 **Sampling theory**

Explains how sample statistics behave across repeated samples.

3 **Scientific inference**

Uses data, assumptions and transparent criteria to support research conclusions.

In academic writing, statistical inference should be connected to the research question, not reported as isolated numbers.

COMPARISON TABLE

Descriptive vs. Inferential Statistics

Aspect	Descriptive Statistics	Inferential Statistics
Purpose	Summarize data that were observed	Draw conclusions about a wider population
Typical outputs	Mean, median, mode, standard deviation, charts	Confidence intervals, p-values, hypothesis tests, regression estimates
Scope	The sample or dataset only	Population beyond the observed data
Uncertainty	Usually not central	Central to interpretation
Research question	“What does this dataset show?”	“What can this sample suggest about the population?”

The Logic of Statistical Inference

Population
What we want to know

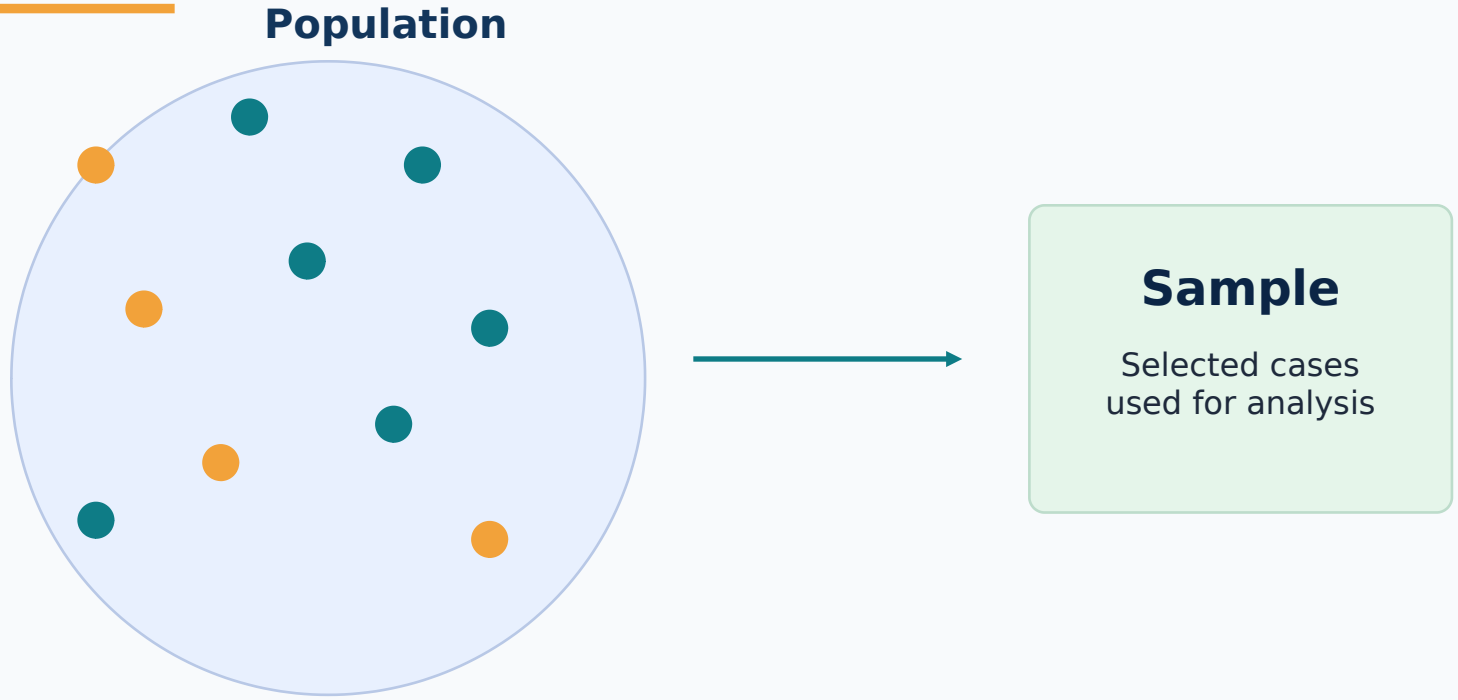
Sample
What we observe

Statistic
What we calculate

Inference
What we conclude

Inference is strongest when sampling is appropriate, measurement is valid and assumptions are checked.

Population, Sample and Sampling Error



Sampling error

The natural difference between a sample statistic and the true population parameter. It occurs because a sample is not the whole population.

Good sampling design reduces bias; larger samples often reduce random sampling error.

Probability and Random Variation

Inferential statistics relies on probability because sample results vary by chance. Probability helps researchers estimate how surprising, precise or uncertain a result is.

Random variation

Differences that occur because samples are selected from a population with natural diversity.

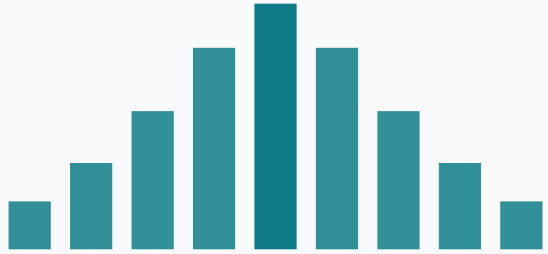
Probability model

A simplified mathematical description of how sample results are expected to vary.

Uncertainty

A measurable part of research conclusions, not a weakness to hide.

Chance has patterns when many samples are considered.

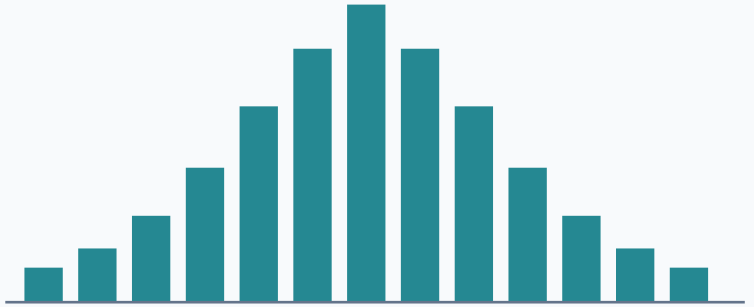


Sampling Distributions and Standard Error

A sampling distribution shows how a statistic, such as a sample mean, would vary across many repeated random samples. Its spread is summarized by the standard error.

Standard error

The estimated standard deviation of a sampling distribution. Smaller standard error means more precise estimates.



Sampling distribution of a statistic

Formula idea: standard error decreases when sample size increases, assuming other conditions are comparable.

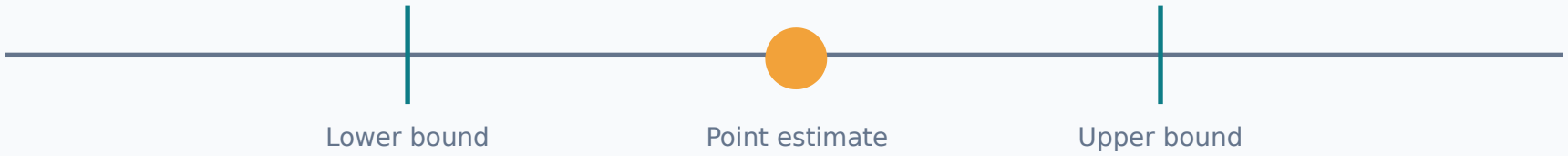
Estimation: Point Estimates and Intervals

Point estimate

A single value used to estimate a population parameter. Example: sample mean = 72.4.

Interval estimate

A range of plausible values for the population parameter. Example: 68.1 to 76.7.



Confidence Intervals

A confidence interval is a range of values calculated from sample data that is used to estimate an unknown population parameter. It communicates precision and uncertainty.

Correct interpretation

A 95% confidence interval means that the method would capture the true parameter in about 95% of repeated samples under the same conditions.

Common misunderstanding

It does not mean there is a 95% probability that this specific fixed interval contains the parameter after it has been calculated.

Wider interval = more uncertainty. Narrower interval = more precision, assuming the method is appropriate.

Hypothesis Testing: Core Logic

Hypothesis testing evaluates whether sample data provide enough evidence against a default assumption, usually called the null hypothesis.

Null hypothesis (H_0)

A statement of no effect, no difference or no relationship. It is the default position tested with data.

Alternative hypothesis (H_1)

A statement that an effect, difference or relationship exists in the population.

Evidence from data

The sample result is compared to what would be expected if H_0 were true.

A hypothesis test supports a decision: reject H_0 or fail to reject H_0. It does not prove H_0 is true.

STEP-BY-STEP PROCESS

Hypothesis Testing Process

1

State hypotheses

Define H_0 and H_1 based on the research question.

2

Choose alpha

Set the significance level before analysis, commonly .05 when appropriate.

3

Select test

Choose a test based on variables, design and assumptions.

4

Calculate result

Compute the test statistic, p-value and effect size.

5

Interpret

Connect statistical result to the research question and limitations.

P-Values, Alpha and Significance

p-value

The probability of getting a result at least as extreme as the observed one, assuming the null hypothesis is true.

Alpha (α)

The pre-set threshold for deciding whether the result is statistically significant.

Significance

If p ≤ α, the result is considered statistically significant under the chosen test.

Type I Error, Type II Error and Power

Concept	Meaning	Simple explanation
Type I error	Rejecting a true null hypothesis	A false positive
Type II error	Failing to reject a false null hypothesis	A false negative
Power	Probability of detecting a real effect when it exists	Sensitivity of the study

Improving power

Use appropriate sample size, reliable measures, strong research design, clear hypotheses and suitable statistical tests.

Main Types of Inferential Tests

Tests of differences

t-test, ANOVA, Mann–Whitney U, Kruskal–Wallis

Tests of relationships

Correlation, regression, chi-square test

Estimation methods

Confidence intervals for means, proportions and differences

Prediction models

Linear regression, logistic regression and related models

The “right” test depends on the research question, variable types, study design and assumptions.

Parametric vs. Non-Parametric Tests

Feature	Parametric tests	Non-parametric tests
Typical data	Continuous data with assumptions about distribution	Ordinal, ranked or non-normal data
Examples	t-test, ANOVA, Pearson correlation	Mann–Whitney U, Wilcoxon, Kruskal–Wallis, Spearman correlation
Strength	Often powerful when assumptions are met	Useful when assumptions are not met or data are ranked
Caution	Assumptions must be checked	May answer a slightly different question than a parametric test

APPLICATION

Selecting the Appropriate Statistical Test

Research purpose	Variables/design	Common test examples
Compare two means	One categorical group variable with two groups + one continuous outcome	Independent-samples t-test
Compare three or more means	One categorical group variable with 3+ groups + one continuous outcome	ANOVA
Test association between categories	Two categorical variables	Chi-square test of independence
Measure relationship between continuous variables	Two continuous variables	Pearson correlation or regression
Predict outcome from multiple predictors	Continuous or categorical outcome with predictors	Linear or logistic regression

APPLICATION

Assumptions and Data Conditions

Independence

Observations should not improperly depend on each other.

Measurement level

Variables should match the chosen test.

Distribution shape

Some tests assume approximate normality.

Equal variance

Some group comparisons assume similar variability.

Sample size

Small samples require extra caution and careful interpretation.

Outliers

Extreme values can distort estimates and tests.

APPLICATION

Effect Size and Practical Significance

Statistical significance tells us whether a result is unlikely under the null hypothesis. Effect size tells us how large or meaningful the result is.

Statistical significance

Can be influenced strongly by sample size. A tiny effect can be significant in a very large sample.

Practical significance

Asks whether the effect is large enough to matter in theory, policy or practice.

Good reporting includes p-values, confidence intervals, effect sizes and substantive interpretation.

Step-by-Step Inferential Analysis Workflow

1. Define question

Specify population, variables and hypothesis.

2. Plan sampling

Choose a sampling strategy and target sample size.

3. Collect data

Use reliable and ethical measurement procedures.

4. Screen data

Check missing data, outliers and assumptions.

5. Analyze

Run appropriate test and calculate estimates.

6. Interpret

Report results with uncertainty and limitations.

Practical Examples Across Disciplines

Social sciences

Estimate public attitudes from survey data.

Business & management

Test whether a training program improves sales performance.

Education

Compare exam scores between teaching methods.

Health sciences

Estimate recovery rates and compare treatment groups.

Psychology

Test whether stress is related to sleep quality.

Information technology

Evaluate whether a new interface reduces task completion time.

Detailed Research Scenario

Element	Example application
Research topic	Effect of online formative quizzes on undergraduate statistics achievement
Research problem	Students often struggle with statistics concepts and may need frequent low-stakes feedback.
Research question	Do students who use weekly online quizzes score higher on the final statistics test than students who do not?
Participants	Two sections of undergraduate research methods students
Data collection	Final test scores, quiz participation records and basic demographic variables
Data analysis	Independent-samples t-test or ANCOVA if prior achievement is controlled; report confidence interval and effect size.
Expected interpretation	If the quiz group scores higher with meaningful effect size, results may support using formative quizzes, while acknowledging design limitations.

Advantages of Inferential Statistics

Generalization

Supports conclusions about populations when sampling is appropriate.

Efficiency

Makes research possible without collecting data from everyone.

Decision support

Provides transparent criteria for evaluating evidence.

Uncertainty communication

Shows precision through intervals and error estimates.

Theory testing

Helps evaluate hypotheses and research models.

Comparability

Enables systematic comparison across studies.

Limitations and Challenges

Poor sampling can produce biased or non-generalizable results.
Assumption violations can make test results misleading.
Statistical significance may be confused with practical importance.

Small samples can produce unstable estimates and low power.
P-values are often misinterpreted or overemphasized.
Causal claims require appropriate research design, not statistics alone.

Statistics cannot rescue weak measurement, biased sampling or poorly designed research.

EVALUATION

Common Mistakes by Beginning Researchers

Using the wrong test

Choosing tests without considering variables or design.

Misreading p-values

Treating p as the probability that H_0 is true.

Ignoring assumptions

Skipping diagnostics and data screening.

Overclaiming findings

Generalizing beyond the sample and context.

No effect size

Reporting significance without magnitude.

Selective reporting

Showing only results that support the hypothesis.

RECOMMENDATIONS

Best Practices for Correct Application

1. Begin with a clear research question and analysis plan.
2. Use sampling and measurement methods appropriate to the population.
3. Check assumptions before relying on test results.
4. Report confidence intervals and effect sizes, not only p-values.
5. Interpret findings in relation to theory, context and limitations.
6. Be transparent about missing data, exclusions and alternative analyses.

Ethical Considerations in Statistical Inference

Privacy and consent

Participants should understand how their data will be used and protected.

Confidentiality

Data should be reported in ways that prevent identification of individuals.

Bias and fairness

Sampling and interpretation should avoid systematically excluding groups.

Transparency

Researchers should report methods, assumptions and limitations honestly.

Academic integrity

Avoid p-hacking, data manipulation, fabricated results and selective reporting.

Responsible conclusions

Do not make causal or population claims that the design cannot support.

CLASSROOM EXERCISE

Activity: Match the Research Question to the Test

Activity objective

Students practice selecting an inferential test based on the research question, variables and design.

Instructions

In small groups, read three short research questions. Identify the outcome variable, predictor/group variable and a suitable test. Explain your choice.

Expected outcome

Students should justify test selection using variable type, number of groups and study purpose rather than memorization.

1

Research question

Do two teaching methods produce different mean test scores?

2

Research question

Is gender associated with preferred learning mode?

3

Research question

Does screen time predict sleep quality score?

Discussion Questions

Why is random sampling important for generalization?
How should researchers interpret a non-significant result?
Why can a statistically significant result still be practically unimportant?
What problems arise when p-values are used as the only evidence?
How do confidence intervals improve research reporting?
When might a non-parametric test be preferred?
What ethical risks appear when researchers selectively report findings?

Knowledge Check

1. What is the difference between a parameter and a statistic?
2. What does sampling error mean?
3. Name one purpose of a confidence interval.
4. In hypothesis testing, what does the null hypothesis usually represent?
5. What does a p-value describe?
6. Give one example of a Type I error.
7. Which test might compare mean scores across three groups?
8. Why should effect size be reported?

Answer Key and Key Takeaways

Answer key

1. Parameter = population value; statistic = sample value.
2. Natural difference between sample statistic and population parameter.
3. To estimate a parameter with a range that shows uncertainty.
4. Usually no effect, no difference or no relationship.
5. Probability of data as extreme as observed if H_0 is true.
6. False positive: rejecting a true null hypothesis.
7. ANOVA.
8. It shows magnitude and practical importance.

Key takeaways

• Inferential statistics uses samples to make cautious claims about populations.
• Estimation and hypothesis testing both depend on uncertainty.
• Test selection depends on the research question, variables and assumptions.
• Reporting should include interpretation, effect size, confidence intervals and limitations.

Conclusion: Inferential statistics is a core research tool because it helps scholars move from data to defensible evidence-based conclusions.

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Thank You

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